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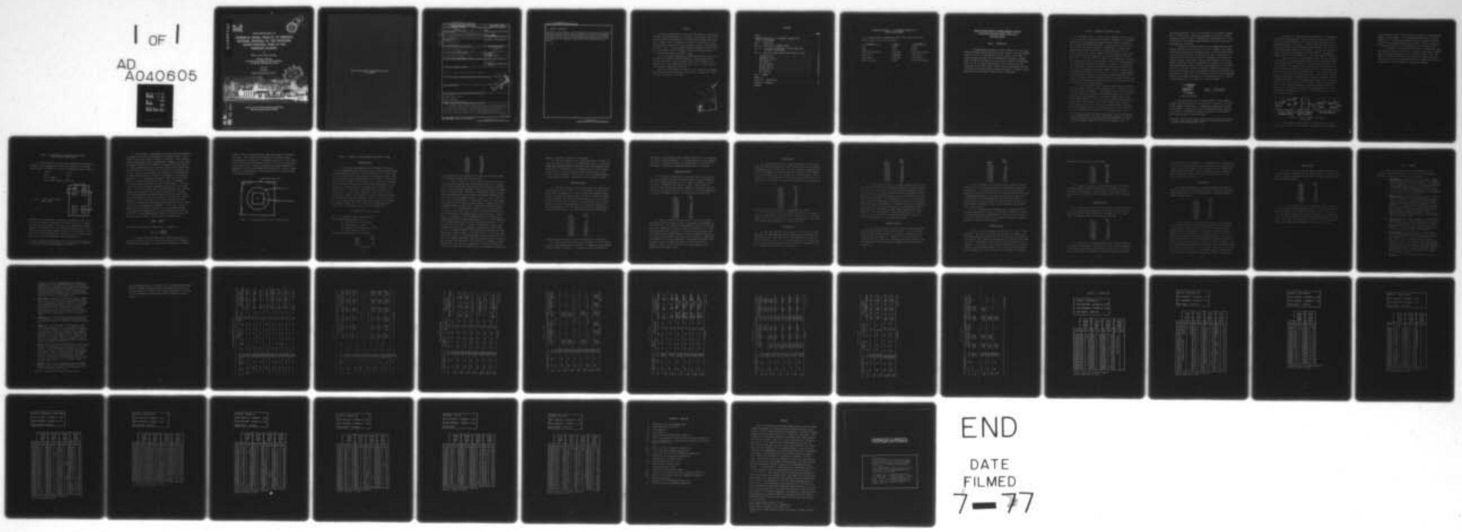

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NUMERICAL MODEL RESULTS OF DREDGED MATERIAL DISPOSAL AT TEN PROPOSED OCEAN DISPOSAL SITES IN THE HAWAIIAN ISLANDS

by

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May 1977

Final Report

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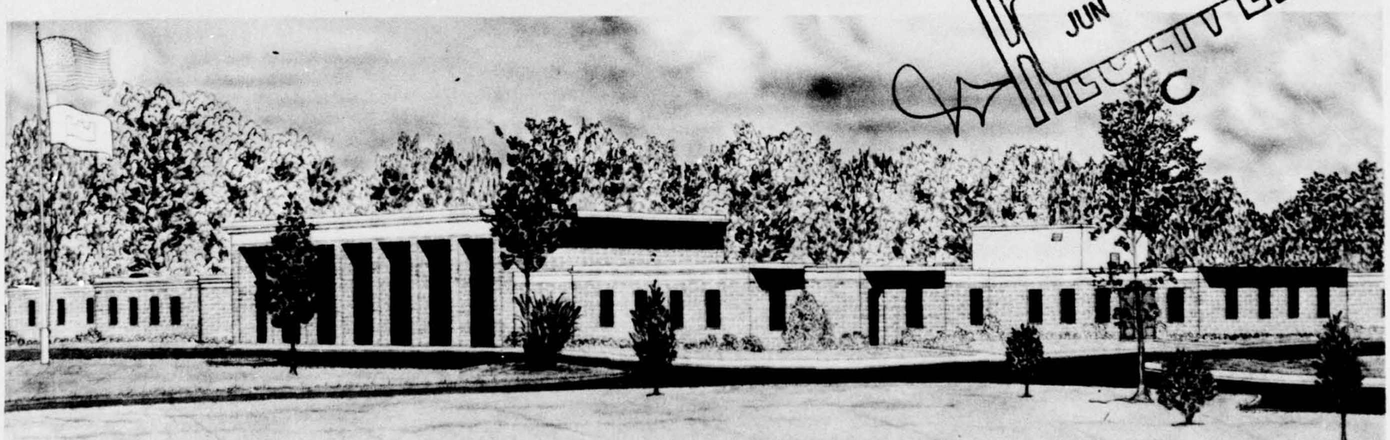

Prepared for U. S. Army Engineer Division, Pacific Ocean
APO San Francisco, California 96558

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER WES-MP- Miscellaneous Paper H-77-6	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) NUMERICAL MODEL RESULTS OF DREDGED MATERIAL DISPOSAL AT TEN PROPOSED OCEAN DISPOSAL SITES IN THE HAWAIIAN ISLANDS. (6)		5. TYPE OF REPORT & PERIOD COVERED Final report,
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Billy H. Johnson, Barry W. Holliday		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station, Hydraulics Laboratory, P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (12) 48 p.
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer Division, Pacific Ocean, Building 230, Fort Shafter, APO San Francisco, California 96558		12. REPORT DATE (11) May 1977
		13. NUMBER OF PAGES 44
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Disposal areas
Dredged material disposal
Hawaiian Islands
Mathematical models
Pacific Ocean disposal sites

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

A numerical model developed by Tetra Tech, Inc., which traces the movement of dredged material disposed in the aquatic environment has been employed at 10 proposed ocean disposal sites in the Hawaiian Islands. The primary objective of the model applications was to provide a qualitative description of the behavior of the disposed material with a corresponding estimate of how much of the material reaches the bottom of each of the 1000-yd-radius disposal sites.
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20. ABSTRACT (Continued).

In addition to model results, a brief description of the numerical model and the rationale for selection of the basic input data at the Pacific Ocean disposal sites are presented. Results from the study indicate that for the particular input data used, at most of the sites the majority of the material will leave the disposal site as suspended sediment rather than being deposited on the bottom.

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PREFACE

The study reported herein, which involved numerically modeling the disposal of dredged material at 10 proposed ocean disposal sites in the Hawaiian Islands, was authorized in a letter dated 6 August 1976, subject: "Numerical Model on Material Transport in Ocean Waters at Ten Proposed Ocean Disposal Sites in the Hawaiian Islands." The study was conducted at the U. S. Army Engineer Waterways Experiment Station (WES) during the period December 1976-March 1977 and was sponsored by the U. S. Army Engineer Division, Pacific Ocean.

Dr. B. H. Johnson, Mathematical Hydraulics Division, and Mr. B. W. Holliday, Environmental Effects Laboratory, conducted the study and prepared this report under the general supervision of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, and M. B. Boyd, Chief of the Mathematical Hydraulics Division.

Director of WES during the conduct of this study and the preparation and publication of this report was COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
yards	0.9144	metres
knots (international)	0.5144444	metres per second
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
feet per second	0.3048	metres per second

NUMERICAL MODEL RESULTS OF DREDGED MATERIAL DISPOSAL AT TEN PROPOSED OCEAN DISPOSAL SITES IN THE HAWAIIAN ISLANDS

PART I: INTRODUCTION

1. The Mathematical Hydraulics Division (MHD) of the U. S. Army Engineer Waterways Experiment Station (WES) conducted the study reported herein for the U. S. Army Engineer Division, Pacific Ocean (POD). A numerical model developed for the Dredged Material Research Program (DMRP) at WES by Tetra Tech, Inc., was used to accomplish the modeling task. To aid in a better understanding of model results, a brief description of the model and its current state of development and verification is given herein before detailed discussions of results of model applications at the proposed disposal sites are presented.

PART II: DISCUSSION OF NUMERICAL MODEL

2. The DMRP of the U. S. Army Corps of Engineers (CE) has as one of its objectives to provide more definitive information on the environmental aspects of dredging and dredged material disposal operations. This large interdisciplinary program is concerned with all aspects of the dredging and disposal problem, an integral part of which is the determination of where the material goes when discharged into the aquatic environment. Under the DMRP, a numerical model for the instantaneous bottom dump of dredged material has been developed by Tetra Tech, Inc., to fill the need of the DMRP for the capability of predicting the short-term fate of the open-water disposal of dredged materials.* In the model, the behavior of the material is assumed to be separated into three phases: convective descent, during which the dumped cloud falls under the influence of gravity; dynamic collapse, occurring when the cloud impacts the bottom or arrives at the level of neutral buoyancy at which descent is retarded and horizontal spreading dominates; and long-term passive dispersion, commencing when the material transport and spreading is determined more by ambient currents and turbulence than by the dynamics of the disposal operation.

3. In the convective descent phase the initial slug of material, which may consist of up to 12 solid components plus a fluid fraction, takes the shape of a hemisphere. This hemispherical cloud falls through the water column after release from the disposal vessel as a result of its mass and initial momentum. In this phase, ambient fluid is entrained which results in a growth of the falling cloud and a corresponding decrease in its density. The cloud eventually either reaches a neutrally buoyant position in the water column or strikes the bottom. When either takes place, the vertical motion of the cloud is arrested and the cloud begins to collapse with a resulting increase in the

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* M. B. Brandsma and D. J. Divoky, "Development of Models for Prediction of Short-Term Fate of Dredged Material Discharged in the Estuarine Environment," Technical Report D-76-5, May 1976, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

horizontal dimensions. This is the initiation of the dynamic collapse phase. When the rate of horizontal spreading as a result of dynamic collapse becomes less than an estimated rate of spreading due to turbulent diffusion, the collapse phase terminates and the turbulent diffusion phase is initiated.

4. Whenever the downward velocity of the dredged material cloud becomes less than the fall velocity of a solid component, solid particles begin falling from the collapsing cloud. As these particles leave the main body of material, they are stored in small clouds which are characterized by a uniform concentration, thickness, and position in the water column. These small clouds are then allowed to settle and disperse until they become large enough to be inserted into the long-term two-dimensional passive dispersion grid positioned in the horizontal plane. Once small clouds are inserted at particular net points, those net points then have a concentration, thickness, and top position associated with them. This is the manner in which the three-dimensional nature of the problem is handled on a two-dimensional grid. A typical concentration profile at a net point is shown in Figure 1.

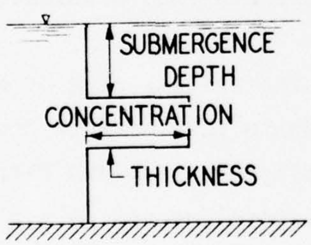

Figure 1. Concentration profile at a net point

5. The model allows for the cohesive nature of fine sediments through calculation of the settling velocity as a function of the suspended sediment concentration. As suggested by Ariathurai,* a lower bound assumed to be the particle fall velocity and an upper bound due to the effect of hindered settling are internally set in the model. Additional discussion is presented later.

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* Private communication, Ranjan Ariathurai, Nielsen Engineering and Research, Inc., Mountain View, Calif.

6. A major set of input data required consists of a characterization of the dredged material. The concentration, density, and voids ratio of each solid fraction plus the bulk density and voids ratio of the mixture must be prescribed. In addition, the settling velocity of each solid must be input; although as previously noted, the settling velocity of cohesive material is calculated. One may also specify the hopper concentration and background concentration of a conservative chemical constituent if computations on such a component are desired.

7. Water depths and a corresponding velocity field must be input at each point of the numerical grid positioned in the horizontal plane over the problem area. The ambient current may be represented in one of three ways. The simplest velocity input consists of vertical profiles for the two horizontal components which do not vary from one grid point to the next and also are time-invariant. Such profiles can only be used in the case of a constant water depth. For the case of a variable depth application, one must either specify time-dependent depth-averaged velocities or a time-dependent two-layered velocity field such as might occur in a highly stratified estuary. The latter representation of such a highly descriptive velocity field would require the expenditure of a great deal of effort. Very few applications of the model would justify such an effort. The different velocity options are illustrated in Figure 2.

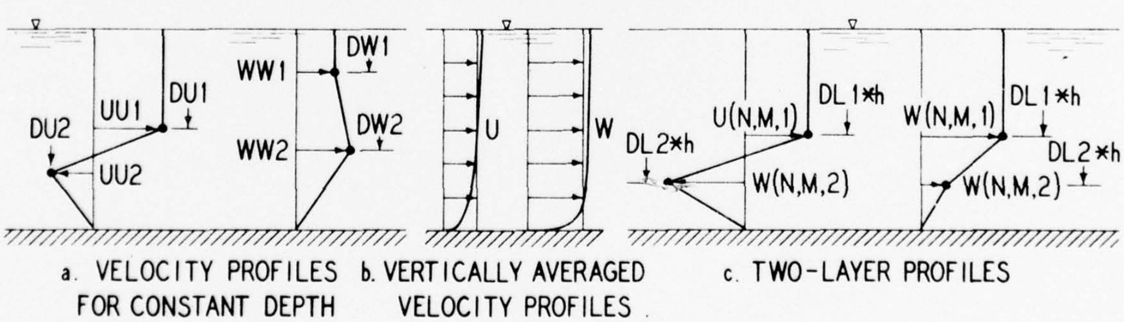

Figure 2. Velocity profiles to be used in the model

8. Output from the model consists of the location, size, and velocity of the cloud plus information concerning each solid component

as a function of time at the end of both the convective descent and the dynamic collapse phases. In the turbulent diffusion phase, the suspended solids concentration and that portion of the water column over which the concentration applies plus the amount of material deposited on the bottom is output at each grid point as a function of time.

9. Although it is believed that the model is conceptually sound and represents the state of the art, it should be noted that the model has not been verified against either laboratory or field data. The DMRP is currently involved in such a verification effort using data collected at several open-water disposal sites by DMRP contractors for documentation of various aspects of the disposal problem.

PART III: RATIONALE FOR SELECTION OF BASIC INPUT DATA AT PACIFIC OCEAN SITES

10. Characterization of the disposal operation was based upon the assumption that all dumps at all sites would be made by the Harding hopper dredge, a description of which is presented below and in Figure 3.

Length	308 ft*
Beam	56 ft
No. of hoppers	8
Total hopper capacity	2682 cu yd

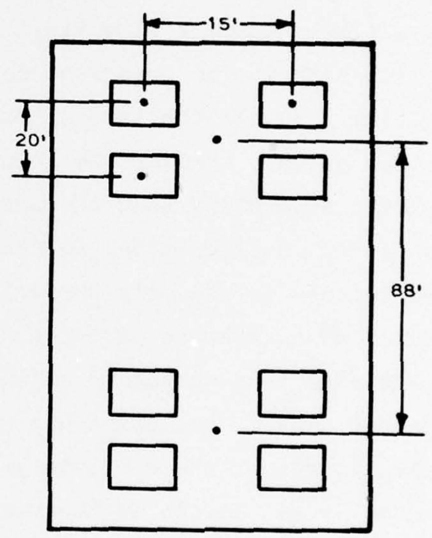

Figure 3. Plan view of Harding hopper dredge

Normally, the four aft doors are opened as essentially one unit, as are the four forward doors. Therefore, the decision was made to consider one half of the total dump as the volume of the instantaneous slug of material to be modeled by the model, under the assumption that a finite length of time would elapse before disposal of the second half. Given the volume of the slug of material to be 1341 cu yd, this then sets the radius of the initial hemispherical cloud to be 25.86 ft.

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

11. A great deal of experimentation with the model was undertaken with regard to the best representation of the ambient current. Since current reversals with depth are common at most sites, it was initially believed that perhaps the best representation (remember the third option previously discussed is not considered economically feasible) would be to assume a constant depth and to use the velocity option which allows for a variation in the vertical but no variation in the horizontal nor in time. After a few experimental runs, however, it was realized that the model would be required to simulate the movement of the disposed material for 3 or 4 hours after the dump in order for even the coarse material to reach the bottom at most sites. Thus, the assumption of a time-invariant flow field no longer seemed reasonable. The only option left was to prescribe depth-averaged velocities as a function of time. In all the initial runs, the dredged material cloud descended rather quickly through the first several hundred feet of the water column, suggesting that the ambient current in the upper water column had little influence on the final deposition of the material. Thus, it was decided to use only currents in the lower portion of the water column as an average over the complete water column as they had a significant effect on suspended solids movement. At each site, one set of current data at one point was utilized to arrive at depth-averaged velocities over the complete grid. These were determined as follows. Assume $\vec{v}^*(t)$ is the depth-averaged current at a point with depth h^*. The conservation of mass of the flow field as expressed below

$$\frac{\partial(uh)}{\partial x} + \frac{\partial(wh)}{\partial z} = 0$$

is ensured if the velocity at other points is computed by

$$\vec{v}(x,z,t) = \frac{\vec{v}^*(t)h^*}{h(x,z)}$$

12. The grid upon which computations were made consisted of a 20-point by 20-point square in the horizontal plane with a spacing of 500 ft between grid points. The center of the disposal site coincided

with the center of the grid, and all dumps were assumed to be made at this point. Water depths were furnished by POD at points within a 3000-ft square at the center of the disposal sites (all of which consist of a circle with a 3000-ft radius); however, no data were readily available at other points. Depths at remaining points were determined by assuming the bottom slope throughout the disposal site could be linearly extended to the boundaries of the computational grid. The grid layout is illustrated in Figure 4.

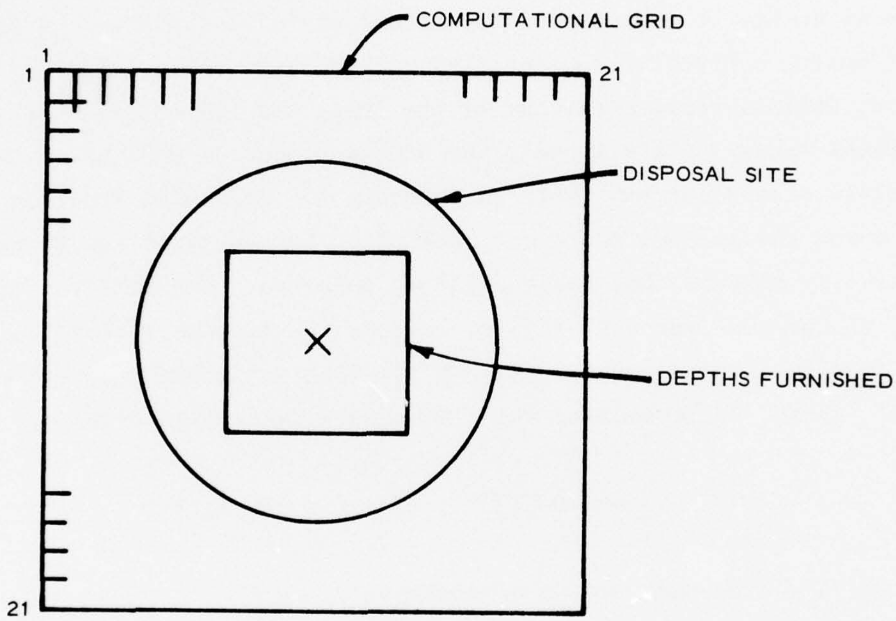

Figure 4. Computational grid in the horizontal plane

PART IV: RESULTS OF MODEL APPLICATION AT SPECIFIC SITES

Honolulu Site 3

13. Initial model experimentation was performed at Honolulu site 3. As previously noted, the first series of runs was made assuming a constant depth and velocities that were allowed to vary in the vertical but were independent of the horizontal coordinates and time. After it was decided to apply a depth-averaged velocity profile, several runs were conducted to demonstrate the effect of (a) a variation of entrainment during convective descent, (b) bulk density variations, (c) different initial representations of the dump, and (d) movement of the disposal vessel. In all runs, the dump was made at 0330 hr on the Honolulu site 3 current table in Appendix A. The solid fraction of all dumps was assumed to be composed of 10 percent sand and 90 percent silty-clay mixture that was considered cohesive. The fall velocity (V_s) of the sand was 0.07 ft/sec, whereas the minimum fall velocity of the cohesive fraction was 0.0017 ft/sec with a maximum velocity of 0.047 ft/sec. Intermediate velocities were determined from

$$V_s = 0.00713^{4/3}; \; 25 \leq C \leq 300 \text{ mg}/\ell$$

where C = suspended solids concentration, mg/ℓ

Base conditions were assumed to be:

- a. Disposal vessel is stationary
- b. Bulk density = 1.40 g/cc
- c. Entrainment coefficient $\alpha_o = 0.235$
- d. Initial radius = 25.86 ft

The ambient density profile is given below:

ρ g/cc	Depth ft
1.0241	0
1.0245	70
1.0247	150

(Continued)

ρ g/cc	Depth ft
1.0250	200
1.0254	335
1.0258	600
1.0266	730
1.0268	1050
1.0271	1250
1.0272	1500

The average depth in the disposal site is about 1450 ft with a variation in depth of perhaps 200 ft over the site.

14. Table 1 (runs 1, 2, 3, and 4) shows that the effect of decreasing the bulk density (ρ_B) of the dredged material is to decrease the distance which the cloud falls before neutral buoyancy is reached. This, in turn, decreases the amount of material that reaches the bottom within the disposal site. The effect of entrainment during convective descent was demonstrated by reducing the entrainment coefficient from 0.235 (the Tetra Tech suggested value) to 0.185. As shown in Table 1 (runs 1 and 5), this reduction in entrainment results in a much longer time required for the convective descent phase to terminate and a corresponding increase of about 300 ft in depth before neutral buoyancy is reached. In all remaining runs, however, the Tetra Tech value of 0.235 will be used since there is no real justification at the present time for reducing the entrainment during convective descent. Table 1 shows that allowing the initial hemispherical cloud to represent the complete dump results in greater penetration into the water column and a corresponding decrease in the time required for deposition of solids on the bottom (runs 3 and 7). However, increasing the volume of the hemispherical cloud with a corresponding decrease in the bulk density to reflect the actual volume of solids results in essentially the same water depth at which collapse occurs (runs 3 and 8). Runs 1 and 6 show that for the case of an instantaneous dump, results are essentially the same in the dynamic computations whether the disposal vessel is stationary or moving. The difference in the results from turbulent diffusion computations is the result of a combination of the way in which small clouds are inserted into the long-term grid and the manner in which real

numbers are changed to integers by the computer.

15. With a bulk density of the dredged material of 1.60 g/cc or less, after 12,000 sec most of the dredged material remains in the water column some 800-1200 ft below the surface, within the boundary of the disposal site. Concentrations of suspended solids are probably about 25 mg/ℓ or less. Most of the coarse sandy material settles to the bottom within the disposal site, but most of the fine-grained material is probably carried out of the disposal site by the ambient current.

Nawiliwili Site 1

16. Two runs were made at this site with both runs being identical except for the time of dump. The first was made at 1450 hr on the current table in Appendix A to reflect a condition of maximum current at 1200 ft, whereas the other was made at 0550 hr to reflect a minimum current condition. The bulk density was assumed to be 1.60 g/cc with the material composed of 3.7 percent sand and 33 percent fine cohesive material. In all the remaining runs at all sites, the radius of the initial hemispherical cloud was taken to be 25.86 ft, corresponding to the volume of four hoppers. The ambient density profile was input as:

ρ g/cc	Depth ft
1.02400	0
1.02407	250
1.02453	317
1.02550	514
1.02737	1039
1.02780	1498
1.02796	1826
1.02810	2351
1.02810	2745
1.02810	3550

The water depth at the point of dump was interpolated to be 2010 ft.

17. As illustrated in Table 2, the cloud falls over 800 ft before a neutrally buoyant position is reached and a subsequent collapse within the water column is initiated. For a dump made under maximum current

conditions, the collapsing cloud is completely swept out of the disposal site before collapse terminates. For the minimum current case, although more time is required, once again the dumped material is swept out of the disposal site before any appreciable deposition on the bottom.

Nawiliwili Site 1A

18. Velocities at Nawiliwili site 1A were taken as an average of the values recorded at depths of 1200 and 1480 ft. Dumping operations at 1910 hr (minimum current) and 1140 hr (maximum current) on the current table in Appendix A were assumed to occur. A bulk density of 1.60 g/cc, with the disposed material composed of 3.7 percent sand and 33 percent fine material, was used in both runs. The interpolated depth at the point of dump was 1600 ft. The ambient density profile was:

ρ g/cc	Depth ft
1.02370	0
1.02377	226
1.02461	292
1.02518	554
1.02560	686
1.02640	751
1.02647	1014
1.02660	1276
1.02681	1539
1.02690	2700

19. Table 2 illustrates that as at site 1 all of the material completely leaves the disposal site for a dump made during maximum current conditions. After 6000 sec approximately 10 percent of the coarse material is deposited on the bottom within the disposal site for a dump during minimum current conditions. It should be noted, however, that after 9000 sec the suspended sediment cloud has completely moved out of the site and thus no additional material will be deposited. Unless the bulk density of the disposed material is significantly increased, based upon model results it seems reasonable to conclude that at both Nawiliwili sites the vast majority of the disposed material will always leave the disposal sites.

Port Allen 2

20. Only one application of the model was conducted at this site since the velocities recorded at 1200 ft appeared to be fairly constant in magnitude over the tidal cycle. The dredged material dumped at Port Allen 2 was assumed to have a bulk density of 1.60 g/cc with 40 percent of the solids being sand and 60 percent fine cohesive material. This results in a sand concentration of 14.7 percent and a fine material concentration of 22.1 percent. The ambient density profile was prescribed as:

ρ g/cc	Depth ft
1.02421	0
1.02421	183
1.02610	511
1.02661	708
1.02706	904
1.02750	1036
1.02751	1232
1.02781	1495
1.02802	1823
1.02810	6040

The depth at the point of dump was interpolated to be 4980 ft.

21. Results shown in Table 2 indicate that the cloud of dumped material cannot reach the bottom within the disposal site. With a water depth of 5000 ft, the coarse material with a fall velocity of 0.07 ft/sec would require approximately 14 hr to reach the bottom.

Port Allen 2A

22. Two runs, each with a bulk density of 1.60 g/cc, reflecting dumps made during maximum and minimum ambient current were made at the Port Allen 2A site. The composition of the material was the same as at the Port Allen 2 site, i.e., 14.7 percent sand and 22.1 percent fine silt and clay. The interpolated depth at the point of dump was 1800 ft with an ambient density profile as given below:

ρ g/cc	Depth ft
1.02421	0
1.02421	183
1.02610	511
1.02661	708
1.02700	904
1.02750	1036
1.02751	1232
1.02781	1495
1.02802	1823
1.02810	3120

23. As illustrated in Table 2, the dumped dredged material cloud falls more than 900 ft through the water column before neutral buoyancy is reached. For the case of a dump occurring during maximum current, i.e., at 2300 hr on the applicable current table in Appendix A, the collapsing cloud is completely transported out of the disposal site by the time collapse terminates. For a dump at 0310 hr, i.e., a minimum current condition, a small quantity of material is deposited on the bottom within the disposal site; however, it appears that even after 12,000 sec less than 10 percent of the total volume of solids has been deposited within the site. Essentially the same comment made concerning the Nawiliwili sites is applicable to the Port Allen sites; i.e., there appears to be little chance for significant deposition of material unless the bulk density is significantly increased.

Honolulu Site 3A

24. Once again, two runs reflecting dumps occurring during maximum and minimum ambient currents were conducted. As at the previous sites, the bulk density was taken to be 1.60 g/cc; however, the disposed material was assumed to be composed of 3.7 percent sand and 33 percent fine silts and clays. The water depth at the point of dump was interpolated to be 1618 ft with the ambient density profile prescribed as:

ρ g/cc	Depth ft
1.02311	0
1.02376	59
1.02429	190
1.02489	518
1.02566	715
1.02600	912
1.02637	1109
1.02664	1371
1.02676	1516
1.02676	1774

25. For a dump made during minimum current conditions, essentially all of the coarse sandy material will be deposited within the disposal site. As indicated in Table 2, none of the fine cohesive material has settled to the bottom after 12,000 sec; however, the cloud is essentially hovering over the disposal site with the edge of the cloud finally reaching the boundary of the site after 12,000 sec. Therefore, there is a possibility that some fine material will be deposited before the ambient current finally transports the suspended cloud out of the site.

26. For a dump made under maximum current conditions, Table 2 indicates that about one third of the sand will be deposited. However, no fine material has been deposited after 12,000 sec and it appears none will be deposited within the site since the cloud has essentially moved out of the site after 12,000 sec.

Kahului Site 7

27. The interpolated depth at the Kahului site 7 point of dump was 749 ft. With such a relatively shallow depth, the bottom is encountered during convective descent for material with a bulk density of 1.60 g/cc. Thus, rather than making runs reflecting different dumping times it was decided to make a second run with a bulk density of 1.40 g/cc. In the first run, the material was composed of 3.7 percent sand and 33 percent fines, whereas in the second run the disposed material consisted of 2.5 percent sand and 22.5 percent fine material.

The ambient density profile is given below:

ρ g/cc	Depth ft
1.02435	0
1.02435	218
1.02480	287
1.02527	352
1.02544	483
1.02572	615
1.02593	680
1.02600	880

28. As Table 2 indicates, even with a bulk density of 1.40 g/cc the dumped material strikes the bottom with a subsequent collapse on the bottom. Essentially all of the material will be deposited on the bottom within the disposal site within about an hour after the dump is made.

Kahului Site 7A

29. At site 7A, the water depth at the point of dump was 1178 ft. As at site 7, runs with bulk densities of 1.60 and 1.40 g/cc were conducted, with the two dumps being made at the same time in the tidal cycle. The ambient density profile was prescribed as:

ρ g/cc	Depth ft
1.02346	0
1.02445	348
1.02472	413
1.02503	544
1.02517	741
1.02593	872
1.02611	938
1.02636	1135
1.02650	1304

30. In both runs, the dumped material falls through over 800 ft of the water column before collapsing at the level of neutral buoyancy. After 5000 sec, approximately 25-30 percent of the sand is on the bottom, but the bulk of the suspended cloud has already been transported

out of the site. After 7500 sec, the suspended cloud is completely out of the site. Since the water depths at site 7A are not extremely deep, it may be that if the complete load of material could be assumed as a single instantaneous dump, collapse would occur on the bottom rather than in the water column. This would, of course, result in a much greater deposition of material.

Hilo Site 9

31. As at the previous site, two runs using bulk densities of 1.60 and 1.40 g/cc were conducted at Hilo site 9 due to the relatively shallow depth of 953 ft at the disposal point. The ambient density profile was prescribed as:

ρ g/cc	Depth ft
1.02465	0
1.02465	200
1.02523	266
1.02529	463
1.02556	528
1.02598	659
1.02643	725
1.02703	856
1.02722	1053

32. For the case of a 1.60 g/cc bulk density, the cloud begins to collapse in the water column but encounters the bottom during the collapse phase. Collapse on the bottom is then initiated with the cloud eventually rising from the bottom before collapse terminates. In comparison, the second dump with a 1.40 g/cc bulk density never encounters the bottom. For the first disposal operation, all of the sand but less than 10 percent of the fine material is deposited within the disposal site before the cloud is transported out by the ambient current. This compares with approximately 80-90 percent of the sand and less than 5 percent of the fines for the 1.40 g/cc dump. Once again, if the complete load could be treated as an instantaneous dump, essentially all of the material would probably be deposited within the disposal site.

Hilo Site 9B

33. As at sites 7, 7A, and 9A, two runs using bulk densities of 1.60 and 1.40 g/cc were made with the numerical model. The depth at the point of dump was interpolated to be 1002 ft, with the ambient density profile input as follows:

ρ g/cc	Depth ft
1.02372	0
1.02372	226
1.02407	358
1.02486	423
1.02512	554
1.02563	620
1.02594	883
1.02645	1014
1.02668	1079

34. At site 9B, the 1.60 g/cc cloud strikes the bottom during convective descent with subsequent deposition of the sand and approximately 75 percent of the fine material within the site. However, the 1.40 g/cc cloud collapses within the water column with only about one fourth of the sand and no fine material deposited within 6000 sec after dump. After 9000 sec, the suspended solids cloud has been transported from the site and no further deposition within the site occurs.

PART V: SUMMARY

35. Based upon model results for an instantaneous dump of 1341 cu yd with a bulk density of 1.60 g/cc, the following general statements concerning each disposal site can be made:

a. Nawiliwili 1. With water depths on the order of 2000 ft, essentially no deposition will occur within the Nawiliwili 1 disposal site under any conditions. The suspended cloud is completely out of the site within 6000 sec after a dump during maximum current. Correspondingly, for a dump during minimum current conditions, concentrations on the order of 50-60 mg/ℓ extending over a thickness of 120 ft exist at the site boundary, whereas concentrations of only 10 mg/ℓ exist within the site.

b. Nawiliwili 1A. With water depths on the order of 1600 ft, very little deposition within the Nawiliwili 1A site occurs. However, if the bulk density was increased and a complete load was considered to be instantaneously dumped, greater deposition would be realized. As at Nawiliwili 1, a dump during maximum current conditions results in no suspended material within the site after 6000 sec, whereas a dump during minimum current conditions results in concentrations on the order of 80-90 mg/ℓ at the boundary and 70 mg/ℓ within the site. These concentrations extend uniformly over approximately 200 ft of the water column.

c. Port Allen 2. Since the water depth at the Port Allen 2 site is about 5000 ft, under no conditions would one expect any deposition within the 1000-yd-radius disposal site. Concentrations on the order of 30 mg/ℓ at the boundary and 40 mg/ℓ within the site are computed after 6000 sec. These concentrations extend over some 200 ft of the water column at a depth of about 900 ft.

d. Port Allen 2A. At the Port Allen 2A site with water depths of approximately 1800 ft and collapse occurring at 900-1000 ft, very little of the dumped material remains within the site. A full load would result in more. After 6000 sec, concentrations of 180 mg/ℓ extending over 40-50 ft of the water column exist at the boundary and within the site for a dump during minimum current. However, after 12,000 sec, the suspended cloud has been diffused and convected such that the concentrations have been reduced to less than 10 mg/ℓ. Under maximum current conditions, the complete cloud leaves the site within 6000 sec.

e. Honolulu 3. With depths around 1400-1500 ft at the

Honolulu 3 site, all coarse material will probably be deposited in the site, whereas most of the fines will be transported out. However, if the complete load could be modeled as an instantaneous dump, most of the fines would be deposited within the site. After 12,000 sec, concentrations in the neighborhood of 25 mg/ℓ exist within the site at 1200 ft from the surface. These extend over approximately 250 ft of the water column.

f. Honolulu 3A. Depths at the Honolulu 3A site are approximately 1600 ft. Essentially the same comments as made about the Honolulu 3 site apply, especially if the dump is made during maximum current conditions. For a dump during minimum current conditions, the cloud remains essentially within the site even after 12,000 sec. Concentrations of about 70 mg/ℓ exist after 6000 sec, and have been reduced to about 40 mg/ℓ after 12,000 sec. These extend over approximately 180 ft of the water column.

g. Kahului 7. With relatively shallow depths of 700-800 ft at the Kahului 7 site, it appears that essentially all the dumped material will be deposited within the disposal site.

h. Kahului 7A. With water depths of approximately 1100-1200 ft at the Kahului 7A site, a substantial portion of the coarse material will be deposited. As discussed at other sites, if the full load was modeled, complete deposition would probably be realized. After 5000 sec, concentrations in the neighborhood of 40-60 mg/ℓ at the boundary and 10-15 mg/ℓ within the site, extending over some 300 ft of the water column, are computed. After 7500 sec, the remaining suspended material has been completely transported out of the site.

i. Hilo 9. With a relatively shallow depth of 250 ft at the Hilo 9 site, essentially all coarse material will be deposited but only approximately 10 percent of the fine material. However, an increase in bulk density and/or an increase in dump size would result in a much greater deposition of the fine cohesive material. Suspended sediment concentrations of approximately 25-30 mg/ℓ exist at the boundary and within the site 6000 sec after the dump. After 12,000 sec, no suspended sediment remains within the site.

j. Hilo 9B. At Hilo site 9B, the water depths are about 1000 ft. Model results indicate that all of the coarse material and about 75 percent of the fines will be deposited within the disposal site.

36. Although it is believed that these results provide a

qualitative description of the behavior of the disposed material under different disposal conditions, again it should be stressed that the numerical model is unverified. Until such a verification is realized, no strict quantitative interpretation should be attached to model results.

Table 1

Model Experimentation at Honolulu 3 Site

	Dump Information					Model Results								
						Convective Descent			Dynamic Collapse			Turbulent Diffusion % Solids on Bottom Within Disposal Site		
Run	R_I ft	ρ_B g/cc	C_S ft^3/ft^3	α_o	Type Dump	t_{CD} sec	R_{CD} ft	Y_{CD} ft	t_{Col} sec	Size ft × ft	Y_{Col} ft	6000 sec	9000 sec	12,000 sec
Base 1	25.86	1.40	Sand 0.025 Fines 0.225	0.235	S	261	222	856	1994	848 X 143	822	Sand -6 Fines-0	Sand -54 Fines-0	Sand -99 Fines-0
2	25.86	1.60	Sand 0.0375 Fines 0.3376	0.235	S	362	280	1105	1915	1139 X 148	1053	Sand -54 Fines- 0	Sand-100 Fines-0	Sand -100 Fines- 1
3	25.86	1.30	Sand 0.0187 Fines 0.1688	0.235	S	190	187	707	1100	627 X 150	665	Sand -0 Fines-0	Run Terminated	
4	25.86	1.20	Sand 0.0125 Fines 0.1125	0.235	S	211	175	656	1090	733 X 88	625	Sand -0 Fines-0	Run Terminated	
5	25.86	1.40	Sand 0.025 Fines 0.225	0.185	S	371	237	1162	1790	910 X 140	1110	Sand -57 Fines- 8	Sand-100 Fines-22	Sand-100 Fines-39
6	25.86	1.40	Sand 0.025 Fines 0.225	0.235	M @ 4Kt	243	218	830	1970	823 X 140	796	Sand -6 Fines-0	Sand -54 Fines-0	Sand -99 Fines-0
7	32.58	1.30	Sand 0.0187 Fines 0.1688	0.235	S	374	276	1058	2313	1207 X 126	991	Sand- 40 Fines-0	Sand- 88 Fines-0	Sand -100 Fines- 1
8	50.0	1.083	Sand 0.0052 Fines 0.0467	0.235	S	192	211	705	1118	710 X 168	657	Sand -0 Fines-0	Run Terminated	

Table 1 (Concluded)

	Dump Information					Turbulent Diffusion					
						Max Conc, Thickness and Top of Fines at Boundary of Site			Max Conc, Thickness and Top of Fines Within Site (Thickness > 100 ft)		
Run	R_I ft	ρ_B g/cc	C_S ft^3/ft^3	α_o	Type Dump	6000 sec	9000 sec	12,000 sec	6000 sec	9000 sec	12,000 sec
Base 1	25.86	1.40	Sand 0.025 Fines 0.225	0.235	S	Contained in Site	Contained in Site	Contained in Site	112 mg/ℓ Tp-940' Tk-135'	73 mg/ℓ Tp-1010' Tk-135'	52 mg/ℓ Tp-1090' Tk-135'
2	25.86	1.60	Sand 0.0375 Fines 0.3376	0.235	S	Contained in Site	1.3 mg/ℓ Tp-1140' Tk-36'	Contained in Site	36 mg/ℓ Tp-1090' Tk-269'	31 mg/ℓ Tp-1140' Tk-269'	26 mg/ℓ Tp-1200' Tk-269'
3	25.86	1.30	Sand 0.0187 Fines 0.1688	0.235	S	Run Terminated					
4	25.86	1.20	Sand 0.0125 Fines 0.1125	0.235	S	Run Terminated					
5	25.86	1.40	Sand 0.025 Fines 0.225	0.185	S	Contained in Site	Contained in Site	Contained in Site	57 mg/ℓ Tp-1250' Tk-214'	34 mg/ℓ Tp-1250' Tk-209'	2/mg/ℓ Tp-1280' Tk-196'
6	25.86	1.40	Sand 0.025 Fines 0.225	0.235	M @ 4kt	Contained in Site	Contained in Site	Contained in Site	47 mg/ℓ Tp-840' Tk-308'	31 mg/ℓ Tp-910' Tk-308'	24 mg/ℓ Tp-990' Tk-308'
7	32.58	1.30	Sand 0.0187 Fines 0.1688	0.235	S	Contained in Site	3.6 mg/ℓ Tp-1080' Tk-38'	0.80 mg/ℓ Tp-1130' Tk-38'	36 mg/ℓ Tp-1030' Tk-265'	31 mg/ℓ Tp-1090' Tk-265'	26 mg/ℓ Tp-1160' Tk-265'
8	50.0	1.083	Sand 0.0052 Fines 0.0467	0.235	S	Run Terminated					

Table 2

Results of Model Applications

	Dump Information			Convective Descent			Dynamic Collapse			Turbulent Diffusion % Solids on Bottom in Disposal Site		
Site	R_I ft	ρ_B g/cc	C_S ft^3/ft^3	t_{CD} sec	R_{CD} ft	$\overline{Y}_{CD}$ ft	t_{Col} sec	Size ft × ft	$\overline{Y}_{Col}$ ft	6000 sec	9000 sec	12,000 sec
1 @ 1450	25.86	1.60	Sand 0.037 Fines 0.330	204	223	860	1360	949 X 114	817	—— Cloud out of site ——		
1 @ 0550	25.86	1.60	Sand 0.037 Fines 0.330	204	223	860	1330	933 X 112	808	Sand - 01 Fines - 0	Sand - 01 Fines - 0	Sand - 01 Fines - 0
1A @ 1910	25.86	1.60	Sand 0.037 Fines 0.330	361	263	1029	2443	1010 X 160	924	Sand - 09 Fines - 0	Sand - 09 Fines - 0	Sand - 09 Fines - 0
1A @ 1140	25.86	1.60	Sand 0.037 Fines 0.330	361	263	1028	2437	1009 X 160	920	——Cloud out of site ——		
2 @ 0140	25.86	1.60	Sand 0.147 Fines 0.221	243	239	929	1521	1023 X 114	869	Material leaves site before reaching bottom		
2A @ 2300	25.86	1.60	Sand 0.147 Fines 0.221	248	242	938	1652	1094 X 118	895	—— Cloud out of site ——		
2A @ 0310	25.86	1.60	Sand 0.147 Fines 0.221	244	241	934	1560	1051 X 110	880	Sand -05 Fines - 02	More material is on bottom but not in the site	

(Continued)

Table 2 (Continued)

Dump Information				Turbulent Diffusion					
				Max Conc, Thickness and Top of Fines at Boundary of Site			Max Conc, Thickness and Top of Fines Within Site		
Site	R_I ft	ρ_B g/cc	C_S ft^3/ft^3	6000 sec	9000 sec	12,000 sec	6000 sec	9000 sec	12,000 sec
1 @ 1450	25.86	1.60	Sand 0.037 Fines 0.330	Cloud out of site					
1 @ 0550	25.86	1.60	Sand 0.037 Fines 0.330	57 mg/ℓ Tp-740 Tk-120	0 - -	0 - -	10 mg/ℓ Tp-740 Tk-120	0 - -	0 - -
1A @ 1910	25.86	1.60	Sand 0.037 Fines 0.330	86 mg/ℓ Tp-980 Tk-217	0 - -	0 - -	70 mg/ℓ Tp-980 Tk-217	0 - -	0 - -
1A @ 1140	25.86	1.60	Sand 0.037 Fines 0.330	Cloud out of site					
2 @ 0140	25.86	1.60	Sand 0.147 Fines 0.221	29 mg/ℓ Tp-905 Tk-219	0 - -	0 - -	39 mg/ℓ Tp-905 Tk-193	0 - -	0 - -
2A @ 2300	25.86	1.60	Sand 0.147 Fines 0.221	Cloud out of site					
2A @ 0310	25.86	1.60	Sand 0.147 Fines 0.221	174 mg/ℓ Tp-935 Tk-44	70 mg/ℓ Tp-940 Tk-44	9 mg/ℓ Tp-945 Tk-44	180 mg/ℓ Tp-935 Tk-44	25 mg/ℓ Tp-940 Tk-44	2 mg/ℓ Tp-945 Tk-44

(Continued)

(Sheet 2 of 6)

Table 2 (Continued)

	Dump Information			Convective Descent			Dynamic Collapse			Turbulent Diffusion % Solids on Bottom in Disposal Site		
Site	R_I ft	ρ_B g/cc	C_S ft^3/ft^3	t_{CD} sec	R_{CD} ft	$\overline{Y}_{CD}$ ft	t_{Col} sec	Size ft × ft	$\overline{Y}_{Col}$ ft	6000 sec	9000 sec	12,000 sec
3A @ 2130	25.86	1.60	Sand 0.037 Fines 0.330	271	254	991	1698	1043 X 134	931	Sand - 0 Fines - 0	Sand - 48 Fines - 0	Sand - 96 Fines - 0
3A @ 0230	25.86	1.60	Sand 0.037 Fines 0.330	271	254	991	1698	1043 X 134	931	Sand - 6 Fines - 0	Sand - 33 Fines - 0	Sand - 34 Fines - 0
										4000 Sec	6000 Sec	8000 Sec
7 @ 2150	25.86	1.60	Sand 0.037 Fines 0.330	119	182	683	1335	2340 X 10	735	Sand -100 Fines - 94	Cloud out of site	
										4000 Sec	6000 Sec	8000 Sec
7 @ 2150	25.86	1.40	Sand 0.025 Fines 0.225	150	182	682	1457	2208 X 12	726	Sand -100 Fines -92	Cloud out of site	
										5000 Sec	7500 Sec	10000 Sec
7A @ 1505	25.86	1.60	Sand 0.037 Fines 0.330	200	230	889	1268	844 X 156	844	Sand - 27 Fines - 0	Cloud out of site	
										5000 Sec	7500 Sec	1000 Sec
7A @ 1505	25.86	1.40	Sand 0.025 Fines 0.225	218	215	825	1104	829 X 128	782	Sand - 30 Fines - 0	Cloud out of site	

(Continued)

Table 2 (Continued)

Dump Information				Turbulent Diffusion					
				Max Conc, Thickness and Top of Fines at Boundary of Site			Max Conc, Thickness and Top of Fines Within Site		
Site	R_I ft	ρ_B g/cc	C_S ft^3/ft^3	6000 sec	9000 sec	12,000 sec	6000 sec	9000 sec	12,000 sec
3A @ 2130	25.86	1.60	Sand 0.037 Fines 0.330	0 - -	0 - -	0.30 mg/ℓ Tp-1040 Tk-180	70 mg/ℓ Tp-970 Tk-180	52 mg/ℓ Tp-1000 Tk-180	42 mg/ℓ Tp-1020 Tk-180
3A @ 0230	25.86	1.60	Sand 0.037 Fines 0.330	62 mg/ℓ Tp-970 Tk-210	52 mg/ℓ Tp-980 Tk-210	5 mg/ℓ Tp-960 Tk-210	49 mg/ℓ Tp-960 Tk-210	42 mg/ℓ Tp-970 Tk-210	2 mg/ℓ Tp-950 Tk-210
				4000 Sec	6000 Sec	8000 Sec	4000 Sec	6000 Sec	8000 Sec
7 @ 2150	25.86	1.60	Sand 0.037 Fines 0.330	17 mg/ℓ Tp-750 Tk-14	0 - -	0 - -	3 mg/ℓ Tp-750 Tk-9	0 - -	0 - -
				4000 Sec	6000 Sec	8000 Sec	4000 Sec	6000 Sec	8000 Sec
7 @ 2150	25.86	1.40	Sand 0.025 Fines 0.225	11 mg/ℓ Tp-740 Tk-21	0 - -	0 - -	2 mg/ℓ Tp-740 Tk-21	0 - -	0 - -
				5000 Sec	7500 Sec	1000 Sec	5000 Sec	7500 Sec	10000 Sec
7A @ 1505	25.86	1.60	Sand 0.037 Fines 0.330	62 mg/ℓ Tp-820 Tk-334	0 - -	0 - -	15 mg/ℓ Tp-820 Tk-345	0 - -	0 - -
				5000 Sec	7500 Sec	10000 Sec	5000 Sec	7500 Sec	10000 Sec
7A @ 1505	25.86	1.40	Sand 0.025 Fines 0.225	42 mg/ℓ Tp-825 Tk-331	0 - -	0 - -	10 mg/ℓ Tp-817 Tk-331	0 - -	0 - -

(Continued)

Table 2 (Continued)

	Dump Information			Convective Descent			Dynamic Collapse			Turbulent Diffusion % Solids on Bottom in Disposal Site		
Site	R_I ft	ρ_B g/cc	C_S ft^3/ft^3	t_{CD} sec	R_{CD} ft	$\bar{Y}_{CD}$ ft	t_{Col} sec	Size ft × ft	$\bar{Y}_{Col}$ ft	6000 sec	9000 sec	12,000 sec
9 @ 1950	25.86	1.60	Sand 0.037 Fines 0.330	180	216	830	2183	2230 X 19	793	Sand - 100 Fines - 06	Sand - 100 Fines - 07	Sand - 100 Fines - 07
9 @ 1950	25.86	1.40	Sand 0.024 Fines 0.216	184	198	753	1099	809 X 104	707	Sand - 86 Fines - 02	Sand - 86 Fines - 02	Sand - 86 Fines - 02
9B @ 2200	25.86	1.60	Sand 0.037 Fines 0.330	227	235	911	1958	2916 X 15	922	Sand - 100 Fines - 77	Sand - 100 Fines - 77	Sand - 100 Fines - 77
9B @ 2200	25.86	1.40	Sand 0.024 Fines 0.216	300	228	880	2041	1114 X 82	800	Sand - 24 Fines - 0	Sand - 24 Fines - 0	Sand - 24 Fines - 0

(Continued)

Table 2 (Concluded)

Dump Information				Turbulent Diffusion					
				Max Conc, Thickness and Top of Fines at Boundary of Site			Max Conc, Thickness and Top of Fines Within Site		
Site	R_I ft	ρ_B g/cc	C_S ft^3/ft^3	6000 sec	9000 sec	12,000 sec	6000 sec	9000 sec	12,000 sec
9 @ 1950	25.86	1.60	Sand 0.037 Fines 0.330	26 mg/ℓ Tp-805 Tk-158	19 mg/ℓ Tp-830 Tk-156	0 - -	31 mg/ℓ Tp-817 Tk-158	12 mg/ℓ Tp-828 Tk-153	0 - -
9 @ 1950	25.86	1.40	Sand 0.024 Fines 0.216	18 mg/ℓ Tp-696 Tk-290	7 mg/ℓ Tp-710 Tk-276	0 - -	31 mg/ℓ Tp-696 Tk-290	2 mg/ℓ Tp-705 Tk-276	0 - -
9B @ 2200	25.86	1.60	Sand 0.037 Fines 0.330	10 mg/ℓ Tp-930 Tk-74	1 mg/ℓ Tp-935 Tk-68	0 - -	9 mg/ℓ Tp-930 Tk-74	0 - -	0 - -
9B @ 2200	25.86	1.40	Sand 0.024 Fines 0.216	17 mg/ℓ Tp-830 Tk-50	0 - -	0 - -	4 mg/ℓ Tp-830 Tk-50	0 - -	0 - -

(Sheet 6 of 6)

APPENDIX A: CURRENT DATA

STATION - NAWILIWILI #1
DATE INSTALLED - OCTOBER 22, 1976
DATE RECOVERED - OCTOBER 23, 1976
WATER DEPTH - 3600 FEET

	METER # 10 DEPTH 150'		METER # 11 DEPTH 600'		METER # 12 DEPTH 1200'		METER # 13 DEPTH 3580'	
TIME	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.
1400	301	1.50	205	1.49	259	1.31	(DEPLOYED AND LOST)	
1500	211	1.32	203	.90	002	.71		
1600	209	1.21	216	83	348	.56		
1700	203	.84	321	.41	346	.11		
1800	204	.78	86	.26	343	.39		
1900	139	26	353	.37	344	39		
2000	147	43	101	34	347	.35		
2100	117	.39	296	31	003	.46		
2200	133	.41	316	34	006	.39		
2300	121	.43	317	19	335	.20		
2400	129	.46	132	26	335	.11		
0100	178	.78	146	31	334	.41		
0200	192	1.28	139	37	351	27		
0300	197	96	104	39	356	34		
0400	191	1.17	140	34	358	39		
0500	191	1.27	288	43	351	41		
0600	197	.85	328	69	339	.11		
0700	183	92	332	37	008	000		
0800	174	79	336	.90	351	31		

Current direction in degrees magnetic.
Current velocities in knots.

STATION - NAWILIWILI #1A

DATE INSTALLED - OCTOBER 21, 1976

DATE RECOVERED - OCTOBER 22, 1976

WATER DEPTH - 1500 FEET

	METER # 10 DEPTH 150'		METER # 11 DEPTH 600'		METER # 12 DEPTH 1200'		METER # 13 DEPTH 1480'	
TIME	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.
1000	113	0.47	132	.39	6.	.61	350	.26
1100	257	.66	182	.51	349	.63	357	.81
1200	264	.48	184	.73	353	.63	000	1.04
1300	271	.37	216	.83	345	.92	358	1.02
1400	269	42	193	.84	345	.88	351	.81
1500	(DATA NOT YET PROCESSED)		221	.92	348	51	356	.61
1600			186	.76	357	.37	8	.76
1700			155	.53	338	.39	6	.51
1800			147	37	21	.61	3	.81
1900			49	39	19	51	356	.46
2000			30	46	16	31	345	31
2100			38	.60	22	26	17	.41
2200			344	33	332	34	7	.37
2300			207	39	346	.79	354	.34
000			213	58	337	1.20	343	.61
100			188	69	352	.83	347	.51
200			229	1.00	353	1.11	6	.32
300			227	1.02	345	.37	15	.39
400			210	.87	350	.34	5	.58
500			211	.74	005	000	18	34
600			218	.56	13	.10	5	.74
700			123	.58	9	.48	5	53
800			138	43	13	31	18	.73
900			111	58	9	.39	8	.41

Current direction in degrees magnetic.
Current velocity in knots.

STATION - PORT ALLEN #2

DATE INSTALLED - NOVEMBER 4, 1976

DATE RECOVERED - NOVEMBER 5, 1976

WATER DEPTH - 5200 FEET

	METER # 10 DEPTH 1200'		METER # 11 DEPTH 5180'	
TIME	DIR.	VEL.	DIR.	VEL.
1400	116	0.31	01	0.58
1500	74	.19	355	.34
1600	329	34	337	.41
1700	325	.26	352	.73
1800	284	.31	017	1.41
1900	267	34	017	1.39
2000	334	.31	016	1.39
2100	333	.48	075	1.30
2200	334	37	281	1.24
2300	352	39	156	.31
0000	027	.34	007	1.80
0100	053	.26	006	1.80
0200	55	34	006	1.80
0300	42	.39	85	1.23
0400	59	37	086	1.23
0500	65	.39	91	1.23
0600	65	.31	308	1.30
0700	30	.34	312	1.29
0800	87	.34	312	1.29
0900	77	.43	026	.73

Current direction in degrees magnetic.
Current velocity in knots.

STATION - PORT ALLEN #2A

DATE INSTALLED - NOVEMBER 3, 1976

DATE RECOVERED - NOVEMBER 4, 1976

WATER DEPTH - 1740 FEET

	METER #10 DEPTH 600'		METER # 11 DEPTH 1200'		METER # 12 DEPTH 1720'	
TIME	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.
1300	236	37	285	.63	(DEPLOYED AND LOST)	
1400	012	.35	273	42		
1500	297	.48	273	41		
1600	276	.69	306	63		
1700	287	.41	298	43		
1800	308	.37	306	43		
1900	278	.59	284	37		
2000	322	.58	290	58		
2100	307	.58	113	34		
2200	137	.31	320	43		
2300	76	.26	344	1.38		
0000	25	.34	317	.95		
0100	354	.31	317	.73		
0200	302	.37	347	.74		
0300	303	.48	16	.31		
0400	286	39	36	.20		
0500	319	48	37	.26		
0600	311	46	326	.34		
0700	328	34	270	26		
0800	101	31	335	26		
0900	341	1.29	351	1.10		

Current direction in degrees magnetic.
Current velocity in knots.

STATION - HONOLULU #3 (SHORT TERM)

DATE INSTALLED - OCTOBER 19, 1976

DATE RECOVERED - OCTOBER 20, 1976

WATER DEPTH - 1500 FEET

	METER # 10 DEPTH 150'		METER # 11 DEPTH 600'		METER # 12 DEPTH 1200'		METER # 13 DEPTH 1480'	
TIME	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.
1400	273	.69	294	31	314	.51	338	.42
1500	251	.46	234	46	330	31	352	.41
1600	212	.61	234	65	001	34	351	.34
1700	262	.74	272	39	16	35	349	37
1800	245	71	237	0.00	12	.31	350	31
1900	262	.65	225	.43	359	.34	350	37
2000	275	.90	215	41	12	.31	350	46
2100	267	1.07	184	.37	13	.11	350	0.00
2200	248	67	241	.39	18	0.00	351	31
2300	240	.51	211	.31	13	0.00	354	26
0000	193	.35	165	.26	332	.11	358	37
0100	188	65	209	.31	327	11	359	0.00
0200	193	46	178	.31	326	.19	001	34
0300	245	53	223	.43	324	.26	15	43
0400	239	63	242	.70	342	.20	23	58
0500	199	54	214	43	328	.20	26	34
0600	202	39	203	.34	322	0.00	26	0.00
0700	170	.37	178	.31	10	0.00	13	20
0800	202	39	207	.31	12	.19	3	41
0900	193	41	227	.27	17	.34	5	0.00
1000	255	39	238	.31	17	34	351	0.00
1100	241	26	245	34	332	0.00	355	0.00
1200	198	26	229	.26	327	.11	359	0.00
1300	13	31	320	31	326	.37	357	0.00
1400	8	31	334	31	325	.53	26	43
1500	35	.20	.95	67	17	.74	27	.84

Current direction in degrees magnetic.
Current velocity in knots.

STATION - HONOLULU #3A

DATE INSTALLED - OCTOBER 2, 1976

DATE RECOVERED - OCTOBER 3, 1976

WATER DEPTH - 1680 FEET

	METER # 10 DEPTH 150'		METER # 11 DEPTH 600'		METER # 12 DEPTH 1200'		METER # 13 DEPTH 1660'	
TIME	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.
1400	239	0.71	249	0.32	356	0.00	358	1.69
1500	241	0.39	242	0.43	331	0.11	199	1.91
1600	241	0.84	248	0.41	323	0.20	205	1.78
1700	219	0.86	217	0.39	337	0.20	187	2.09
1800	256	0.73	267	0.35	347	0.11	186	1.99
1900	270	0.59	328	0.35	17	0.20	161	2.92
2000	268	0.46	310	0.61	19	0.00	143	2.92
2100	235	0.78	277	0.71	325	0.00	339	1.01
2200	218	0.56	268	0.54	329	0.59	594	1.23
2300	203	0.39	283	0.61	338	0.41	356	0.83
0000	219	0.80	258	0.80	317	0.00	355	0.39
0100	244	0.54	278	0.63	328	0.37	285	1.45
0200	249	0.69	327	0.49	341	0.32	122	0.54
0300	239	0.63	206	0.11	325	0.00	157	0.11
0400	196	0.65	170	0.00	129	0.00	102	0.47
0500	183	0.63	71	0.00	186	0.11	6	1.66
0600	150	0.39	60	0.39	178	0.00	12	1.75
0700	162	0.32	38	0.41	355	0.84	0	1.06

Current direction in degrees magnetic.
Current velocity in knots.

STATION - KAHULUI #7

DATE INSTALLED - OCTOBER 17, 1976

DATE RECOVERED - OCTOBER 18, 1976

WATER DEPTH - 780 FEET

	METER # 10 DEPTH 50'		METER # 11 DEPTH 150'		METER # 12 DEPTH 600'		METER # 13 DEPTH 760'	
TIME	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.
1500	250	.10	275	.34	16	.26	17	.39
1600	250	.31	223	.34	13	37	19	.46
1700	246	0.00	197	.37	10	.53	19	31
1800	354	26	244	31	16	48	345	.34
1900	329	31	186	34	17	56	340	.43
2000	98	50	359	43	22	26	332	.34
2100	102	31	344	31	19	10	337	.31
2200	238	51	357	34	319	10	347	74
2300	320	46	339	34	317	34	359	56
0000	349	58	354	31	317	46	348	34
0100	351	.69	359	31	318	41	337	.26
0200	356	.58	311	31	323	31	349	.35
0300	345	.61	323	26	330	19	352	.27
0400	39	.44	304	26	328	0.00	18	.39
0500	65	35	337	26	348	0.00	19	.34
0600	52	39	335	19	354	0.00	18	.31
0700	16	46	346	26	337	.10	357	.41
0800	77	46	12	26	321	.10	347	.26
0900	55	26	85	37	322	.10	333	.34
1000	350	26	325	39	322	.31	344	.46
1100	336	0.00	72	76	332	.58	351	.81
1200	51	1.44	37	15	14	67	22	.76

Current direction in degrees magnetic.
Current velocity in knots.

STATION - KAHULUI #7A

DATE INSTALLED - OCTOBER 16, 1976

DATE RECOVERED - OCTOBER 17, 1976

WATER DEPTH - 1200 FEET

	METER # 10 DEPTH 50'		METER # 11 DEPTH 150'		METER # 12 DEPTH 600'		METER # 13 DEPTH 1180'	
TIME	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.
1300	291	1.28	237	.27	18	.20	350	.54
1400	288	.77	287	.43	16	.42	347	.11
1500	247	.63	271	.43	18	.45	348	.26
1600	282	.80	298	.48	13	45	348	.46
1700	288	.99	287	.46	18	.45	349	.41
1800	266	.84	267	37	21	.45	350	39
1900	237	.83	269	53	17	.43	349	31
2000	287	.87	275	.63	14	.36	348	.11
2100	276	.90	296	.56	13	.39	348	0.00
2200	259	.91	291	.56	16	.36	348	.20
2300	255	.85	310	.51	14	.36	348	.20
0000	248	.80	285	.46	16	.42	349	26
0100	242	1.00	320	44	340	.44	349	26
0200	293	.90	280	.61	328	.32	348	.31
0300	267	.78	268	.49	351	.11	348	.34
0400	233	.90	245	.-7	357	0.00	349	27
0500	263	.97	247	.61	11	.27	349	34
0600	241	.84	246	56	17	.37	349	43
0700	245	.76	259	65	13	20	349	35
0800	282	.76	259	46	349	31	349	20
0900	263	.81	303	35	334	0.00	348	.26

Current direction in degrees magnetic.
Current velocity in knots.

STATION - HILO #9

DATE INSTALLED - OCTOBER 12, 1976

DATE RECOVERED - OCTOBER 13, 1976

WATER DEPTH

	METER # 10 DEPTH 50'		METER # 11 DEPTH 150'		METER # 12 DEPTH 600'		METER # 13 DEPTH 1120'	
TIME	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.
1400	101	.87	154	.37	270	.54	337	.20
1500	242	.87	268	.31	295	.46	347	0.00
1600	281	.86	284	.35	291	.44	355	.11
1700	279	.81	296	.37	293	.39	352	.11
1800	220	.81	299	.41	359	.56	20	.37
1900	224	.63	292	.44	326	.35	19	.35
2000	243	.61	315	.44	309	.35	15	.35
2100	142	.39	302	.27	297	.26	353	.27
2200	145	.46	306	.35	290	.26	342	.27
2300	169	.46	115	.20	287	.34	339	.27
0000	185	.32	29	.11	292	.37	337	.27
0100	242	.35	45	.39	293	.35	339	.27
0200	213	.39	38	.35	303	.31	337	.20
0300	213	.41	35	.46	307	.11	339	.20
0400	186	.41	287	.41	330	.11	337	.20
0500	197	.49	265	.41	310	.27	337	.31
0600	215	.59	262	.39	322	.27	338	.2-
0700	220	.20	302	.49	321	.20	338	.11
0800	228	.71	299	.35	311	0.00	350	.11
0900	146	1.11	233	.37	302	.20	20	.31

Current direction in degrees magnetic.
Current velocity in knots.

STATION - HILO #9B

DATE INSTALLED - OCTOBER 13, 1976

DATE RECOVERED - OCTOBER 14, 1976

WATER DEPTH - 1020 FEET

	METER # 10 DEPTH 50'		METER # 11 DEPTH 150'		METER # 12 DEPTH 600'		METER # 13 DEPTH 1000'	
TIME	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.	DIR.	VEL.
1700	295	.44	274	.37	324	.27	305	.27
1800	262	.41	258	46	328	.35	312	.38
1900	262	.53	253	.61	330	.20	308	.47
2000	295	.44	280	54	320	.20	320	47
2100	346	.39	311	.56	322	.20	329	.45
2200	333	.48	313	.56	321	.27	338	47
2300	299	.63	314	.54	320	.39	338	55
0000	340	.41	324	.49	322	.41	333	53
0100	355	.35	318	41	326	.37	337	.39
0200	358	.27	322	.31	327	.37	328	32
0300	355	.32	295	.35	340	.31	317	.36
0400	330	.32	286	.35	341	.31	319	.39
0500	287	.35	283	.44	341	.27	320	
0600	251	.32	271	.48	343	.20	322	.32
0700	222	.41	273	.54	12	0.00	3-5	27
0800	271	.56	269	46	325	.11	321	20
0900	244	35	259	44	323	.11	323	.36
1000	254	.43	245	46	324	.11	328	.11
1100	239	.48	257	41	237	.20	303	.49
1200	301	.51	252	.41	-	-	305	51
1300	293	.71	252	43	-	-	309	.89

Current direction in degrees magnetic.
Current velocity in knots.

APPENDIX B: NOTATION

C	Suspended solids concentration, mg/ℓ
C_S	Solids concentration, ft^3/ft^3
h	Water depth, ft
h^*	Water depth, ft
R_I	Initial radius of hemispherical cloud, ft
R_{CD}	Radius of hemispherical cloud at end of convective descent, ft
Size	Major and minor axes of elliptical cross section at the end of dynamic collapse, ft
t	Time
t_{CD}	Time to the end of convective descent, sec
t_{Col}	Time to the end of dynamic collapse, sec
Tp	Position of the top of the concentration profile, ft
Tk	Thickness of the concentration profile, ft
u	x-component of the ambient current
$\vec{v}$	Depth-averaged current, ft/sec
$\vec{v}^*$	Depth-averaged current, ft/sec
V_s	Settling velocity, ft/sec
w	Z-component of the ambient current
$\overline{Y}_{CD}$	Centroid of the cloud at the end of convective descent, ft
$\overline{Y}_{Col}$	Centroid of the cloud at the end of dynamic collapse, ft
ρ	Ambient density, g/cc
ρ_B	Bulk density of the dredged material, g/cc
α_o	Convective descent entrainment coefficient

ADDENDUM

Since the completion of the study reported herein, private communications with monitors of dredged material disposal operations at the Honolulu 3 site[1,2] have revealed that the majority of the material dumped reaches the bottom rather quickly, e.g., within 20 to 30 minutes. Similar results have also been observed at the nearby Pearl Harbor disposal site[3] used by the Navy. This is of course in conflict with the general conclusion from the numerical model study presented herein that the majority of the material at most of the 10 sites modeled will be transported from the disposal site as suspended sediment. The most obvious reason for this disagreement lies in the characterization of the material to be dumped. Observations from the field tests noted above indicate that a substantial fraction of the material is composed of rock and coral. In addition, it has been observed that even the cohesive solids settle to the bottom of the hoppers before disposal, with the resulting material possessing a low water content and corresponding high bulk density. It is believed that a large portion of the material then falls from the collapsing cloud as clumps with fall velocities of perhaps 1.0 to 2.0 ft/sec. This is quite different from the characterization of the material used in the numerical model study where the coarse material was assumed to fall with particle fall velocities and the cohesive material to fall with a computed fall velocity having a maximum value of 0.047 ft/sec. Characterization of the material more in accord with the field observations would greatly change the model predictions, i.e., most of the material would reach the bottom rather quickly at most of the disposal sites. This situation emphasizes the importance of proper material characterization in obtaining realistic predictions from these models, particularly when collapse of the disposal cloud in the water column is a real possibility.

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[2] Edward Noda, Consultant to Tetra Tech, Inc.

[3] Michael Allen, Tsunami Research Effort, University of Hawaii, Honolulu, Hawaii.

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Johnson, Billy Harvey
    Numerical model results of dredged material disposal at ten proposed ocean disposal sites in the Hawaiian Islands, by Billy H. Johnson [and] Barry W. Holliday. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1977.
    1 v. (various pagings) illus 27 cm. (U. S. Waterways Experiment Station. Miscellaneous paper H-77-6)
    Prepared for U. S. Army Engineer Division, Pacific Ocean, San Francisco, California.

    1. Disposal areas. 2. Dredged material disposal. 3. Hawaiian Islands. 4. Mathematical models. 5. Pacific Ocean disposal sites. I. Holliday, Barry W., joint author. II. U. S. Army Engineer Division, Pacific Ocean. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper H-77-6)
TA7.W34m no.H-77-6